REMARKS

Claims 1-6 stand provisionally rejected on obviousness-type double patenting over claims 10-23 of copending application Serial Number 09/343,219; claims 1-6 stand rejected provisionally on grounds of obviousness-type double patenting as being unpatentable over claims 1-5 of application Serial Number 10/091,454; and claims 1-6 stand rejected on grounds of obviousness-type double patenting as being unpatentable over claims 1-4 of United States Patent 5,764,515. These grounds of rejection are traversed for the following reasons.

As the Examiner is aware, for an appropriate double patenting rejection, the Examiner must demonstrate that the claims of the current application are mere obvious variants of the claims of the above-identified Assignee's pending applications and United States Patent 5,764,515. It is submitted that the Examiner has not made a prima facie case that the claims of the current application are mere obvious variants of the pending claims and the issued claims of the above-identified applications and patent.

Newly submitted claim 7 and newly submitted claim 23 of the present application respectfully recite as follows:

> A method of gradual deformation of a representation generated by sequential simulation, of a stochastic model, which is limited to a Gaussian stochastic model, of a physical quantity z in a heterogeneous medium, in order to constrain the stochastic model which is not limited to a Gaussian stochastic model to a set of data collected in the medium by means of previous measurements and observations, relative to a state or the structure thereof, comprising applying a stochastic model gradual deformation algorithm to a Gaussian vector (Y) with N mutually independent variables that is connected to a uniform vector U with N mutually independent uniform variables by a Gaussian distribution function (G), so as to form a chain of realizations u(t) of vector U, and using these realizations u(t) to generate realizations z(t) of the physical quantity that are adjusted to the data

and

A method for gradual deformation of a realization generated by use of a sequential simulation, of a stochastic model not limited to a Gaussian stochastic model of a physical quantity in a heterogeneous medium, in order to constrain the realization to a set of data collected in the medium by means of previous measurements and observations, relative to the state or the structure thereof, comprising:

a) generating a first uniform realization of at least a part of the stochastic model using a sequential simulation, the first realization corresponding to a realization of a uniform vector and transforming the first uniform realization to a corresponding first Gaussian realization;

b) generating at least a second uniform realization of the part of the stochastic model independent from the first realization, at least one of the realizations corresponding to a realization of the uniform vector, and transforming the at least one second uniform realization to a corresponding second Gaussian realization;

c) linearly combining the first Gaussian realization and the second Gaussian realization, with coefficients of the combination of the first and second Gaussian realizations being such that a sum of squares of the coefficients is equal to 1, transforming the linearly combined Gaussian realization to a combined uniform realization and forming a realization of the stochastic model by sequential simulation with the combined uniform realization;

d) forming an objective function that measures misfit between sets of data computed from the formed realization of the stochastic model representing the physical quantity, and the corresponding data measured from the heterogeneous medium; and

e) minimizing the objective function with respect to the coefficients until obtaining an optimized realization of the stochastic model.

Claim 10 of Serial No. 09/343,219 recites as follows:

A method of providing an optimized Gaussian, optimized lognormal or optimized truncated Gaussian stochastic model of a distribution of a parameter in a heterogeneous underground medium by fitting a set of measured non linear data forming a response of the medium, comprising:

a) generating a first realization of at least a part of the stochastic model and deducing therefrom a first set of non-linear data forming a response of the model;

b) generating at least one other realization of a same part of the stochastic model independent from the first realization and deducing therefrom corresponding sets of non-linear data as a response of the model;

c) forming a realization of the stochastic model by linearly combining the first realization and the at least one other realization, with coefficients of the combination being such that a sum of squares of the coefficients is equal to 1 and deducing therefrom a corresponding set of non-linear data as a response of the model;

d) forming an objective function that measures a misfit between the sets of non-linear data deduced from step c) with corresponding non-linear data measured from the medium; and

e) minimizing the objective function with respect to the coefficients of the combination of the realizations until an optimized realization of the stochastic model is obtained.

Claim 10 requires a precise sequence of steps of generating a first realization, generating a second realization independent of the first realization, forming a realization of the stochastic model by linearly combining the realizations dependent upon coefficients, forming an objective function that measures a misfit and minimizing the objective function. With respect to independent claims 7 and 23, it is submitted that independent claim 10 of Serial No. 09/343,219 as discussed above, is drawn to substantially different subject matter than independent claims 7 and 23 of the present application. There is no basis in the record why a person of ordinary skill in the art would be led to modify claim 10 of Serial No. 09/343,219 to arrive at the subject matter of the independent claims of the present application or the dependent claims.

The only rationale supplied by the Examiner is the conclusory statement that "it would have been obvious to one having ordinary skill in the art at the time the invention was made to apply the method described in application number 09/343,219 to gradually deform sequential simulations of the heterogeneous

environment, such as an underground zone." The Examiner has <u>not</u> provided any analysis of the differences between independent claim 1, which corresponds to claim 7, and moreover, it is submitted that newly submitted claim 23 also pertains to substantially different subject matter. The conclusion that the only difference between the claims of application Serial No. 09/343,219 and claim 1, its counterpart newly submitted claim 7 and new claim 23 is gradual deformation of sequential simulations of a heterogeneous environment, such as an underground zone is erroneous when the respective claims are actually compared as discussed above.

The processing of the particular parameters set forth in claims 7 and 23 are not mere obvious variations of claim 10 of Serial No. 09/343,219. It is submitted that a person of ordinary skill in the art would not be led to modify the subject matter of claim 10 to arrive at the subject matter of claims 7 and 23 and the claims dependent therefrom.

Independent claim 1 of Serial No. 10/091,454 recites:

> A method for gradually deforming an initial realization formed from measurements or observations and defining the distribution of a set of objects in a zone of a heterogeneous medium such as a geologic structure, generated by simulation of an object type stochastic model, the objects being distributed in the zone according to a Poisson point process in form of figurative points with a point density $\lambda(x)$ varying according to their position (x) in the zone, characterized in that it comprises :
> - generating a realization of a uniform random vector according to which the position of each object is defined while respecting density $\lambda(x)$, and
> - gradually modifying the uniform random vector according to a gradual deformation procedure, so as to obtain gradual migration of each object and consequently gradual change in the distribution of the objects in the zone, until a final realization best adjusted to parameters relative to the structure of the medium, such as hydrodynamic parameters, is obtained, which gives a realistic representation of the configuration of the objects in the modeled heterogeneous medium.

A comparison of independent claim 1 as quoted above with claims 7 and 23 of the present application reveals that there is no relationship between claim 1 and claims 7 and 23. Again, the Examiner relies upon an oversimplification of the subject matter of claim 1 of Serial Number 10/091,454 as requiring only gradual deformation of sequential simulations of the heterogeneous environment such as an underground zone. In fact, claim 1 of Serial No. 10/091,454 differs substantially from claims 7 and 23 by reciting a Poisson point process in a form of figurative points with a point density $\lambda(x)$ varying according to their position (x), generating a realization of uniform random vectors relative to the density $\lambda(x)$, and gradually modifying of the uniform random vector which is related to $\lambda(x)$ in order to give a realistic representation of the configuration of the objects in the modeled heterogeneous medium. It is submitted that a person of ordinary skill in the art would not be motivated to modify the subject matter of claim 1 of Serial No. 10/091,454 to achieve claims 7 and 23 and the claims dependent therefrom.

Independent claim 1 of United States Patent 5,764,515 recites:

> A method for predicting the evolution of the production of an underground zone containing fluids, such as a hydrocarbon reservoir, comprising the following states:
>
> a) an initial geologic model deformed by a set of parameters x is constructed by integrating available data and an inversion method is applied to determine the values of parameters allowing the response of the model to be adjusted with a production history known for said zone,
>
> b) one or several possible scenarios of the production evolution are defined and, for each of these scenarios, observed data are added to fictitious data at given future times corresponding to hypotheses,
>
> c) for each of said scenarios, the parameters of said model are adjusted in order to reproduce both real measurements from the production history and data added at future times, and an inversion procedure is applied in order to obtain, for each scenario, a new set of parameters x characterizing a modified geologic model and corresponding to the scenario hypotheses, and

d) for each of these modified geologic models, simulations are achieved in order to establish new production forecasts.

The Examiner again asserts that "to gradually form sequential simulations of a heterogeneous environment, such as an underground zone relative to the subject matter of claim 1 of the '515 Patent , would result in the subject matter of claim 1 of the present application." Again, the Examiner relies upon an oversimplification of the subject matter of claim 1 of the '515 Patent. Claim 1 of the '515 Patent recites an initial geologic model deformed by a set of parameters x, one or several possible scenarios of a production evolution being defined and for each scenario observed data are added to fictitious data, for each of the scenarios parameters of the model are adjusted to reproduce real measurements and an inversion procedure is applied to obtain a new set of parameters x characterizing a modified logical model and finally, for each modified geological model, simulations are obtained in order to establish new production forecasts. This subject matter has nothing to do with the subject matter of claims 7 and 23 of the present application. Moreover, a person of ordinary skill in the art would not be led to modify claim 1 of the '515 Patent to arrive at the subject matter of independent claims 7 and 23 and the dependent claims of the present application without resort to impermissible hindsight.

Moreover, the Examiner has not even demonstrated that in the prior art gradual deformation of sequential simulations of a heterogeneous environment is obvious relative to the claimed subject matter of the claims of present application.

In view of the foregoing amendments and remarks, it is submitted that each of the claims in the application is in condition for allowance. Accordingly, early allowance thereof is respectfully requested.

To the extent necessary, Applicants petition for an extension of time under 37 C.F.R. §1.136. Please charge any shortage in fees due in connection with the filing of this paper, including extension of time fees, to Deposit Account No. 01-2135 (612.39651X00) and please credit any excess fees to such Deposit Account.

Respectfully submitted,

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Attachment

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PATENT

METHOD INTENDED FOR GRADUAL DEFORMATION OF SEQUENTIAL SIMULATIONS OF A HETEROGENEOUS MEDIUM SUCH AS AN UNDERGROUND ZONE

ABSTRACT

~~Method intended for~~ A method of gradual deformation of representations or realizations, generated by sequential simulation, ~~of a~~ not ~~necessarily~~limited to a Gaussian stochastic model of a physical quantity z in a meshed heterogeneous medium, in order to adjust ~~them~~ the model to a set of data relative to the structure or the state of the medium which are collected by previous measurements and observations.

[-] ~~It essentially~~ The method comprises applying a stochastic model gradual deformation algorithm to a Gaussian vector with N mutually independent variables which is connected to a uniform vector with N mutually independent uniform variables by ~~the~~ a Gaussian distribution function so as to define realizations of the uniform vector, and using these realizations to generate representations of ~~this~~ the physical quantity z that are adjusted to the data.

~~Applications for example for visualizing the statistical configuration of a quantity: permeability of an underground reservoir, atmospheric pollution, etc.~~

BACKGROUND OF THE INVENTION

~~FIELD OF THE INVENTION~~

Field of the Invention

The ~~object of the~~ present invention ~~is~~ relates to a method ~~intended for~~ of gradual deformation of representations or realizations, generated by sequential simulation, of a ~~not necessarily Gaussian stochastic~~ model of a heterogeneous medium which is not limited to a Gaussian stochastic model, based on a gradual deformation algorithm of Gaussian stochastic models.

~~The method according to the invention finds applications in underground zones modelling intended to generate representations showing how a certain physical quantity is distributed in an underground zone (permeability z for example) and best compatible with observed or measured data: geologic data, seismic records, measurements obtained in wells, notably measurements of the variation with time of the pressure and of the flow rate of fluids from a reservoir, etc.~~

~~BACKGROUND OF THE INVENTION~~

Description of the Prior Art

In French patent application ~~FR-~~98/09,018 ~~is described~~ a method ~~intended for gradual deformation of~~ is described which gradually deforms a stochastic (Gaussian type or similar) model of a heterogeneous medium such as an underground zone, constrained by a set of parameters relative to the structure of the medium. This method

comprises drawing a number p (p=2. for example) of realizations (or representations) independent of the model or of at least part of the selected model of the medium from all the possible realizations and one or more iterative stages of gradual deformation of the model by performing one or more successive linear combinations of p independent initial realizations~~,~~ and then composite realizations are successively obtained possibly with new draws, ~~etc.,~~ the coefficients of this combination being such that the sum of their squares is 1.

Gaussian or similar models are well-suited for modelling continuous quantity fields ~~and they~~ but are therefore ill-suited for modelling zones crossed by fracture networks or channel systems for example.

The most commonly used geostatistical simulation algorithms are those referred to as sequential simulation algorithms. Although ~~they~~ sequential simulation algorithms are particularly well-suited for simulation of Gaussian models, ~~they do~~ these algorithms are not ~~imply~~ in principle ~~a limitation~~ limited to this type of model.

A geostatistical representation of an underground zone is formed for example by subdividing ~~it~~ thereof by a network with N meshes and by determining a random vector with N dimensions $Z = (Z_1, Z_2, \ldots Z_N)$ best corresponding to measurements or observations obtained on the zone. As shown for example by Johnson, M.E.; in « "Multivariate Statistical Simulation" » ; Wiley & Sons, New York, 1987, this approach reduces the problem of the creation of an N-dimensional vector to a series of N one-dimensional problems. Such a random vector is neither necessarily multi-Gaussian nor stationary. Sequential simulation of Z first involves the definition of an order according

to which the N elements (Z_1, Z_2,...Z_N) of vector Z are generated one after the other. Apart from any particular case, it is assumed that the N elements of Z are generated in sequence from Z_1 to Z_N. To ~~draw~~ determine a value of each element Z_i, (i = 1, ..., N), the following operations have to be carried out:

a) building the distribution of Z_i, conditioned by (Z_1, Z_2..Z_{i-1})

$F_c(Z_i) = P(Z_i \leq z_i / Z_1, Z_2, \ldots Z_{i-1})$; and

b) ~~drawing~~ determining a value of Zi from distribution F_c (Z_i).

In geostatistical practice, sequential simulation is frequently used to generate multi-Gaussian vectors and non-Gaussian indicator vectors. The main function of sequential simulation is to determine conditional distributions F_c (z_i) (i = 1,..., N). Algorithms and softwares for estimating these distributions are for example described in:

- Deutsch, C.V. et al, ~~«~~"GSLIB (Geostatistical Software Library) and User's Guide"~~»~~ ; Oxford University Press, New York, Oxford 1992.

Concerning ~~drawing~~ determining the values from distribution F_c (z_i), there also is a wide set of known algorithms.

~~We consider the~~ The inverse distribution method is considered by means of which a realization of Z_i: $z_i = F_c^{-1}(u_i)$ is obtained, where u_1 is taken from a uniform distribution between 0 and 1. A realization of vector Z therefore corresponds to a realization of vector U whose elements U_1, U_2, ..., U_N, are mutually independent and evenly distributed between 0 and 1.

It can be seen that a sequential simulation is an operation S which converts a uniform vector $U = (U_1, U_2, \ldots U_N)$ to a structured vector $Z = (Z_1, Z_2, \ldots, Z_N)$:

$$Z=S(U) \qquad (1).$$

The problem of the constraint of a vector Z to various types of data can be solved by constraining conditional distributions $F_c(z_i)$ $(i = 1, \ldots, N)$ and/or uniform vector $U = (U_1, U_2, \ldots, U_N)$.

Recent work on the sequential algorithm was focused on improving the estimation of conditional distributions $F_c(z_i)$ by geologic data and seismic data integration.

An article by Zhu, H. et al ~~can be mentioned for example~~: ~~«~~"Formatting and Integrating Soft Data : Stochastic Imaging via the Markov-Bayes Algorithm"~~»~~ in Soares, A., Ed. Geostatistics Troia 92, vol.1 : Kiuwer Acad. Publ., Dordrecht, The Netherlands, pp.1-12, 1993 is an example.

However, this approach cannot be extended to integration of non-linear data such as pressures from well tests and production records, unless a severe linearization is imposed. Furthermore, since any combination of uniform vectors U does not give a uniform vector, the method for gradual deformation of a stochastic model developped in the aforementioned patent application cannot be directly applied within the scope of the sequential technique ~~reminded~~ described above.

The method according to the invention thus allows ~~to make~~ making the two approaches compatible, ~~i.e.~~ that is to extend the formalism developped in the aforementioned patent application to gradual deformation of realizations, generated by sequential simulation, of a ~~not necessarily~~ model which is not limited to a Gaussian stochastic model.

~~DEFINITION OF THE METHOD~~
SUMMARY OF THE INVENTION

The method allows gradual deformation of a representation or realization, generated by sequential simulation, of a model which is not ~~necessarily~~ limited to a Gaussian stochastic model of a physical quantity z in a heterogeneous medium such as an underground zone, in order to constrain ~~it~~ the model to a set of data collected in the medium by previous measurements and observations relative to the state or the structure thereof.

~~It is characterized in that it~~The method of the invention comprises applying an algorithm of gradual deformation of a stochastic model to a Gaussian vector (Y) having a number N of mutually independent variables that is connected to a uniform vector (U) with N mutually independent uniform variables by a Gaussian distribution function (G), so as to define a chain of realizations u(t) of vector (U), and using these realizations u(t) to generate realizations z(t) of this physical quantity that are adjusted in relation to the (non- linear) data.

According to a first embodiment, the chain of realizations u(t) of uniform vector (U) is defined from a linear combination of realizations of Gaussian vector (Y) whose combination coefficients are such that the sum of their squares is one.

According to another embodiment, gradual deformation of a number n of parts of the model representative of the heterogeneous model is performed while preserving the continuity between these n parts of the model by subdividing uniform vector (U) into a number n of mutually independent subvectors.

The method of the invention finds applications in modelling underground zones which generates representations showing how a certain physical quantity is distributed in an underground zone (permeability z for example) and which is compatible in the best manner with observed or measured data: geologic data, seismic records, measurements obtained in wells, notably measurements of the variation with time of the pressure and of the flow rate of fluids from a reservoir, etc.

BRIEF DESCRIPTION OF THE DRAWINGS

Other features and advantages of the method according to the invention will be clear from reading the description hereafter of a non limitative example, with reference to the accompanying drawings wherein:

[-] ~~Figure~~ Fig. 1 shows the medial layer of a realization of a facies model used as a reference, generated by sequential simulation of indicatrices,

[-] ~~Figure~~ Fig. 2 shows the variation with time of the pressure obtained in a well test for the reference model,

[-] ~~Figures~~ Figs. 3A to 3E respectively show five initial realizations of the medial layer of a reservoir zone, constrained only by the facies along the well,

[-] ~~Figures~~ Figs. 4A to 4E respectively show, for these five realizations, the bottomhole pressure curves in the reference model compared with those corresponding to the initial models,

[-] ~~Figures~~ Figs. 5A to 5E respectively show five realizations of the medial layer of the ~~fades~~ facies model conditioned to the facies along the well and adjusted in relation to the pressure curve obtained by well tests,

[-] ~~Figures~~ Figs. 6A to 6E respectively show, for the five realizations, the bottomhole pressure curves in the reference model compared with those corresponding to the adjusted models,

[-] ~~Figures~~ Figs. 7A to 7E respectively show how the objective functions respectively corresponding to these five examples vary with the number of iterations,

[-] ~~Figures~~ Figs. 8A to 8E show the gradual deformations generated by an anisotropy coefficient change on a three-facies model generated by sequential simulation of indicatrices, and

[-] ~~Figures~~ Figs. 9A to 9E show the local gradual deformations of a three-facies model, generated by sequential simulation of indicatrices.

DETAILED DESCRIPTION OF THE ~~METHOD~~INVENTION

~~We consider a~~ A study zone is considered that is subdivided by an N-mesh grid. ~~and we try to build realizations~~ Realizations or representations of a stochastic model of

a certain physical quantity z representing for example the permeability of the formations in the zone are attempted to be made. The ~~wanted~~ model that is sought must adjust to data obtained by measurements or observations at a certain

Adjustment of a stochastic model to non-linear data can be expressed as an optimization problem. The quantity $f^{obs} = (f_1^{obs}, f_2^{obs}, f_3^{obs} \ldots f_P^{obs})$ designates the vector of the nonlinear data observed or measured in the studied medium ~~studied~~ (the reservoir zone), and the quantity $f = (f_1, f_2, f_3 \ldots f_p)$ is the corresponding vector of the responses of the stochastic model of the permeability $Z = (Z_1, Z_2, \ldots, Z_N)$. The problem of constraining the stochastic model of Z by observations consists in generating a realization z of Z which reduces to a rather low value an objective function that is defined as the sum of the weighted rms errors of the responses of the model in relation to the observations or measurements in the reservoir zone, i.e.:

$$O = \frac{1}{2}\sum_{i=1}^{p} \omega_i (f_1 - f_i^{obs})^2$$

where ω_i, represents the weight assigned to response f_i. Functions f_i (i=1, 2, …, p) and objective function O are functions of vector Z. ~~We are thus faced with~~ This presents an optimization problem of dimension N.

In order to extend the formalism ~~developped~~ developed in the aforementioned patent application to the gradual deformation of realizations generated by, but not necessarily limited to Gaussian sequential simulation, ~~we start~~ a starting point is from a Gaussian vector with N variables Y_i, with i = 1, 2, …, N, mutually independent, of zero

mean and of variance equal to 1, and N mutually independent uniform variables $U_1, U_2, U_3, \ldots U_N$ are defined by:

$$U_i = G(Y_i) \;\; \forall \; i = 1, 2, \ldots, N$$

where G represents the standardized Gaussian distribution function.

Assuming this to be the case, the gradual deformation algorithm ~~developped~~ developed within a Gaussian frame is applied to the Gaussian vector $Y = (Y_1, Y_2, \ldots, Y_N)$ in order to build

a continuous chain of realizations of uniform vector U $(U_1, U_2, \ldots, U_N)$. Given two independent realizations y_A and y_b of Y, the chain of realizations u(t) of vector U obtained with the following relation is defined:

$$u(t) = G(y_a, \cos t + y_b, \sin t) \qquad (2).$$

For each t, u(t) is a realization of vector U. A vector z(t) which is, for each t, a realization of random vector Z is then obtained by sampling of the conditional distribution $F_c\,(z_i)$ (i=1, 2,..., N) using the elements of vector u(t). Parameter t can consequently be adjusted as in the Gaussian case so as to adjust z(t) to non-linear data. This procedure is iterated until satisfactory adjustment is obtained.

~~Adjustment of a facies model to pressure data obtained by means of well tests~~
Adjustment of a Facies Model to Pressure Data Obtained by Means of Well Tests

In order to illustrate application of the stochastic optimization method defined above, ~~we try to adjust~~ adjusting a stochastic reservoir model to pressure data obtained by means of well tests is attempted. Building of the reservoir model ~~derives~~ is derived from a real oil formation comprising three types of facies: two reservoir facies of good quality (facies I and 2) and a reservoir facies of very bad quality (facies 3). Table I defines the petrophysical properties of the three facies:

	K_x (md)	K_y (md)	K_z (md)	Φ (%)	c_t (10^{-5} bar^{-1})
Facies 1	10	10	10	17	*2.1857*
Facies 2	1	1	1	14	2.0003
Facies 3	0.1	0.1	0.001	9	1.8148

In order to represent the specific facies distribution of the oil formation, a binary realization is first generated to represent facies 3 and its complement. Then, in the complementary part of facies 3, another binary realization independent of the first one is generated to represent facies 1 and 2. The formation is discretized by means of a regular grid pattern of 60x59x15 blocks 15mx15mx1.5m in size. An exponential variogram model is used to estimate the conditional distributions. The main anisotropy direction is diagonal in relation to the grid pattern. The ranges of the variogram of facies 3 in the three anisotropy directions are 300m, 80m and 3m respectively. The ranges of the variogram of facies 1 and 2 in the three anisotropy directions are 150m, 40m and 1.5m respectively. The proportions of facies 1, 2, 3 are 6%, 16% and 78% respectively.

A well test has been carried out by means of a finite-difference well test simulator as described by:

Blanc, G. et al: ~~«~~"Building Geostatistical Models Constrained by Dynamic Data - A Posteriori Constraints"~~»~~ in SPE 35478, Proc. NPF/SPE European 3D Reservoir Modelling Conference, Stavenger, Norway, 1996.

The medial layer of a realization used as the reference model for this validation can be seen in ~~Figure~~ Fig. 1. The section of the well that has been drilled runs horizontally through the medial layer of the reservoir model along axis x. The diameter of the well is 7.85cm, the capacity of the well is zero and the skin factors of facies 1, 2 and 3 are 0, 3 and 50 respectively. The synthetic well test lasts for 240 days with a constant flow rate of 5 m^3/day so as to investigate nearly the entire oil field. ~~Figure~~ Fig. 2 shows the pressure variation with time.

The objective was to build realizations of the facies model constrained by the facies encountered along the well and by the pressure curve obtained during well testing. The objective function is defined as the sum of the rms differences between the pressure responses of the reference model and the pressure responses of the realization. Since the dynamic ~~behaviour~~ behavior of the reservoir model is mainly controlled by the contrast between the reservoir facies of good and bad quality, the binary realization used to generate facies 1 and 2 has been fixed first and only the binary realization used to generate facies 3 has been deformed for pressure data adjustment.

The pressure responses resulting from the well tests for the five realizations of Figs.3A to 3E are different from that of the reference model, as shown in Figs. 4A to

4E. Starting respectively from these 5 independent realizations, by using the iterative adjustment method above, ~~we obtain,~~ after several iterations, five adjusted realizations are obtained (Figs. 5A to SE) for which the corresponding pressure curves are totally in accordance with those of the reference model, as shown in Figs. 6A to 6E.

~~**Gradual deformation in relation to the structural parameters**~~

Gradual Deformation in Relation to the Structural Parameters

In many cases, sufficient data for deducing the structural parameters of the stochastic model: mean, variance, covariance function, etc.~~,~~ ~~is~~ are not available. These structural parameters are often given in terms of a priori intervals or distributions. If their values are wrong, it is useless to seek a realization adjusted to non-linear data, It is therefore essential for applications to be able to perform a gradual deformation of a realization with simultaneous modification of random numbers and structural parameters. The sequential simulation algorithm defined by equation (1) makes ~~it~~ possible ~~to change~~ changing, simultaneously or separately, a structural operator S and a uniform vector U. Figs. 8A to 8E show the gradual deformations obtained for a fixed realization of uniform vector U when the anisotropy coefficient is changed.

~~**Local or regionalized gradual deformation**~~

Local or Regionalized Gradual Deformation

When the observations are spread out over different zones of a studied formation ~~studied~~, an adjustment using global deformation would be ineffective because the ~~accordance~~ improvement obtained in a zone could deteriorate ~~it~~ the improvement in another zone. It is therefore preferable to apply gradual deformations zone by zone.

Consider a subdivision of vector U into a certain number n of mutually independent subvectors $U^1, U^2, \ldots, U^n$, which allows ~~to perform~~ performing their gradual deformation individually. Separate application of the gradual deformation algorithm to each subvector $U^1, U^2 \ldots, U^n$ allows ~~to obtain~~ obtaining a function of dimension n of uniform vector U:

$$U(t_1, t_2, \ldots, t_n) = \begin{bmatrix} U^1(t_1) \\ U^2(t_2) \\ \vdots \\ U^n(t_n) \end{bmatrix} = \begin{bmatrix} G(Y_a^1 \cos t_1 + Y_b^1 \sin t_1) \\ G(Y_a^2 \cos t_2 + Y_b^2 \sin t_2) \\ \vdots \\ G(Y_a^n \cos t_n + Y_b^n \sin t_n) \end{bmatrix}$$

where Y^i_a and Y^i_b for any i = 1, 2,..., n, are independent Gaussian subvectors. For a set of realizations of Y^i_a, and Y^i_b, a problem of optimization of n parameters $t_1, t_2, \ldots, t_n$ is solved to obtain a realization that improves or maintains the data adjustment. This procedure can be iterated until satisfactory adjustment is obtained.

Gradual local deformations thus allow ~~to significantly improve~~ significant improvement of the adjustment speed in all the cases where measurements or observations are spread out over different zones of the medium.

The effect of this gradual local deformation on the three-facies model of Figs. 9A to 9E can be clearly seen ~~in these figures~~ therein where only the ~~delimited~~ enclosed left lower part is affected.

The method according to the invention can be readily generalized to gradual deformation of a representation or realization of any stochastic model since generation of a realization of such a stochastic model always comes down to generation of uniform numbers.